DOCUMENT RESUME

ED 271 310 SE 046 664

AUTHOR Roth, Kathleen J.; And Others
TITLE Curriculum Materials, Teacher Talk, and Student Learning: Case Studies in Fifth-Grade Science Teaching. Research Series No. 171.
INSTITUTION Michigan State Univ., East Lansing. Inst. for Research on Teaching.
SPONS AGENCY National Science Foundation, Washington, D.C.; Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE Feb 86
CONTRACT 400-81-0014
GRANT SED-8020022
NOTE 38p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Case Studies; *Elementary School Science; Grade 5; Intermediate Grades; *Learning Strategies; *Misconceptions; Science Education; *Science Instruction; Science Teachers; *Teacher Behavior; Teacher Effectiveness; *Verbal Learning

ABSTRACT

In this paper, the verbal interaction strategies and explanation behaviors of three fifth-grade teachers teaching science units are used to illustrate relationships among curriculum materials, teacher talk, and student learning. Experimental studies with these and other teachers indicate that, if teachers become more sensitive to their students' thinking and need for conceptual change and modify their verbal instruction accordingly, student understanding and learning of science can be improved. Textbooks and other curriculum materials can either help or hinder this process. (Author)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

Research Series No. 171

CURRICULUM MATERIALS, TEACHER TALK, AND STUDENT LEARNING: CASE STUDIES IN FIFTH-GRADE SCIENCE TEACHING

Kathleen J. Roth
Charles W. Anderson
Edward L. Smith

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Kathleen J. Roth

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Research Series No. 171

CURRICULUM MATERIALS, TEACHER TALK, AND STUDENT LEARNING: CASE STUDIES IN FIFTH-GRADE SCIENCE TEACHING

Kathleen J. Roth
Charles W. Anderson
Edward L. Smith

Published By

The Institute for Research on Teaching
252 Erickson Hall
Michigan State University
East Lansing, Michigan 48824-1034

February 1986

Development of this paper was supported in part by the National Science Foundation (Grant No. SED 8020022) and the Institute for Research on Teaching, College of Education, Michigan State University. The Institute for Research on Teaching is funded primarily by the Office of Educational Research and Improvement, United States Department of Education. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the Foundation, the Office, or the Department. (Contract No. 400-81-0014)

Institute for Research on Teaching

The **Institute for Research on Teaching** was founded at Michigan State University (MSU) in 1976 by the National Institute of Education. Following a nationwide competition in 1981, the NIE awarded a second five-year contract to MSU. Funding is also received from other agencies and foundations for individual research projects.

The IRT conducts major research projects aimed at improving classroom teaching, including studies of classroom management strategies, student socialization, the diagnosis and remediation of reading difficulties, and teacher education. IRT researchers are also examining the teaching of specific school subjects such as reading, writing, general mathematics, and science and are seeking to understand how factors outside the classroom affect teacher decision making.

Researchers from such diverse disciplines as educational psychology, anthropology, sociology, and philosophy cooperate in conducting IRT research. They join forces with public school teachers who work at the IRT as half-time collaborators in research, helping to design and plan studies, collect data, analyze and interpret results, and disseminate findings.

The IRT publishes research reports, occasional papers, conference proceedings, a newsletter for practitioners, and lists and catalogs of IRT publications. For more information, to receive a list or catalog, and/or to be placed on the IRT mailing list to receive the newsletter, please write to the IRT Editor, Institute for Research on Teaching, 252 Erickson Hall, Michigan State University, East Lansing, Michigan 48824-1034.

Co-Directors: Jere E. Brophy and Andrew C. Porter

Associate Directors: Judith E. Lanier and Richard S. Prawat

Editorial Staff
Editor: Sandra Gross
Assistant Editor: Patricia Nischan

Abstract

In this paper, the verbal interaction strategies and explanation behaviors of three fifth-grade teachers teaching science units are used to illustrate relationships among curriculum materials, teacher talk, and student learning. Experimental studies with these and other teachers indicate that, if teachers become more sensitive to their students' thinking and need for conceptual change and modify their verbal instruction accordingly, student understanding and learning of science can be improved. Textbooks and other curriculum materials can either help or hinder this process.

CURRICULUM MATERIALS, TEACHER TALK, AND STUDENT LEARNING: CASE STUDIES OF FIFTH-GRADE SCIENCE TEACHING[1]

Kathleen J. Roth,
Charles W. Anderson, and
Edward L. Smith[2]

When asked, "What do you teach in science?", most teachers will first respond by referring to the curriculum materials they use. For many elementary teachers, science instruction *is* the program materials, and the materials most frequently used are student textbooks. Lesson planning and daily instruction are dictated by the page number in the textbook or by the sequence of activities described in the teacher's guide. Like tourists whose trips are planned by travel companies and conducted by tour guides, students are taken through science units by teachers who tend to follow the program with little flexibility.

Thus, curriculum materials, especially student textbooks, play an important role in determining what gets taught in science classrooms. But what effect do they have on student learning? Unfortunately, studies show that students are not learning the concepts that they are taught. In a study by Anderson and Smith (1983a), for example, after five weeks of instruction only 20% of the students in five different fifth-grade classrooms using a popular science textbook (Blecha, Gega, & Green, 1979) understood the key concept that people see because light is reflected off objects and travels to their eyes. There were similar results in a study of nine fifth-grade classrooms using the

---

[1]This paper was presented at the Annual Meeting of the National Reading Conference, Symposium on Teacher Explanatory Talk, Austin, Texas, December 1983.

[2]Kathleen Roth is a senior researcher with the Science Teaching Project and an instructor with the Department of Teacher Education, Michigan State University. Charles Anderson and Edward Smith coordinate the project. Anderson is an assistant professor, and Smith is an associate professor, with the teacher education department.

Science Curriculum Improvement Study (SCIIS) Program (Knott, Lawson, Karplus, Their, & Montgomery, 1978), to study photosynthesis (Roth, Smith, & Anderson, 1983). They failed to learn in spite of the carefully planned instructional materials used by their teachers. These students knew what they had studied ("We did photosynthesis today!"), but they had no real understanding of what it was all about. Their science instruction may have exposed them to new ideas and aroused their curiosity, but it did not change their way of thinking about important scientific concepts.

Why is this so? To investigate the reasons for students' learning failures, we observed and interviewed teachers and students during a unit of science instruction. From these studies we have found that what the teacher says, how sensitive the teacher is to the students' responses to instruction, and how the teacher responds to what the students say are critical to student learning. In addition, curriculum materials play important roles in influencing what the teacher says and how the teacher responds to students.

In this paper, the verbal interaction strategies and explanation behaviors of three fifth-grade science teachers are used to illustrate relationships among curriculum materials, teacher talk, and student learning. Based on our observations of these teachers and from study of their students' learning, we draw implications for science teaching and curriculum materials development.

Research Perspectives

The teachers involved in these initial studies appeared to be "effective" teachers according to the characteristics of effective teachers defined by earlier research (cf. Rosenshine, 1979). For example, these teachers were good managers of student behavior, they kept students involved in academic tasks, and they taught science to the whole class using high rates of factual

level questions. And yet, pre- and posttesting showed that students in these classrooms were making very little progress toward understanding the science concepts taught. In order to understand what was going wrong, we decided to focus our research on the mental lives of teachers and students. What are the teachers thinking about as they plan and teach? What implicit theories of learning guide the way they explain concepts and interact with students? What are students doing with information they receive during instruction? How does their thinking change as a result of what the teacher says during instruction.

A variety of methods were used to investigate the relationships among the curriculum materials, the teacher's thinking and teaching, and the students' learning:

1. Detailed propositional analyses of the curriculum materials to identify intended learning goals
2. Interviews with the teachers to probe their attitudes and beliefs about teaching and learning
3. Pre- and posttests of student learning
4. Clinical interviews with target students
5. Classroom observations and tape recording of teachers and students

These methods made it possible to develop detailed case studies of several of the teachers we observed. This paper summarizes three of these case studies and uses them to illustrate several of our conclusions about classroom use of science curriculum materials. In particular, we focus on class discussions that we observed and on patterns of influence among curriculum materials, teacher talk, and student learning.

The Case Studies

The three case studies presented here were selected from the larger study of elementary science teaching to illustrate different patterns of teacher

talk during science instruction. The first two teachers were observed teaching a unit on light and seeing from the *Exploring Science* textbook (Blecha, Gega, & Green, 1979). The pattern exemplified by Ms. Lane is presented as typical of the text-based science teaching initially observed in the study. Ms. Ramsey used the same textbook but supplemented the text with a set to transparencies designed by researchers (Anderson & Smith, 1983b). The transparencies were intended to help the teacher change interaction patterns with students and focus more explicitly on understanding and shaping student thinking about light and seeing. The third teacher, Ms. Kain, was studied while teaching a unit on photosynthesis in two different years. The first year she used no textbook, relying solely on student experiments and class discussions from the SCIIS Program (Knott et al., 1978). During the second year, she used the same experiments and a researcher-written textbook (Roth, 1985) designed to help the teacher focus on the student thinking required to understand the content.

Ms. Lane

During our observations, Ms. Lane's class was studying light and seeing using the *Exploring Science* text. The unit is divided into three sections: pathways of light, color, and vision. The "Pathways of Light" section discusses basic properties of light (such as reflection, absorption, and refraction), which can then be used to understand both how we see objects in general and how we see color.

Use of the textbook. Typical of many teachers using this textbook, Ms. Lane's explanations and questions to the class related directly to what was written in the textbook. Daily instruction consisted of round-robin oral reading of the text, with pauses to answer questions posed in the text. Her

planning and lesson content were determined by the page numbers to be covered. Since the text presented one idea after another without emphasis on important ideas, without relating one idea to another, and without challenging students' common misconceptions, Ms. Lane's presentations followed the same format. In one lesson, for example, Ms. Lane introduced the following concepts: light as energy, light for seeing, light traveling fast, the speed of light, atoms, photons, sources of light (artificial vs. natural), bioluminescence, uses of light, reasons for light traveling fast, lightening, amplitude, wavelengths, light traveling in straight lines, intensity of light, pioneer uses of candles, electricity providing artificial light, watts, volts, fluorescence, and light not curving. Ms. Lane did not give any overall structure to help students assimilate this barrage of new information.

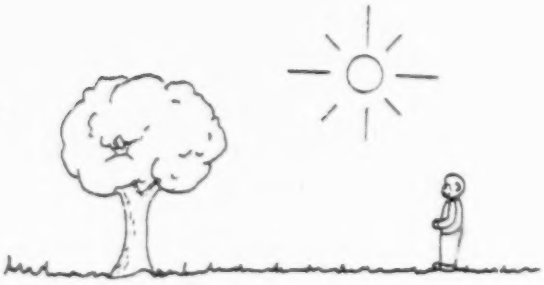
Questioning pattern. The questions posed at the end of paragraphs in the text were used to guide discussion in Ms. Lane's classroom. Unfortunately for Ms. Lane's students, the questions posed in the text were often not the most important ones in terms of helping students learn key concepts. For example, pretests showed that Ms. Lane's students did not have any idea that light enables seeing by bouncing off objects to people's eyes. Rather, students held the idea that light shines on objects, and people then directly perceive the objects. The difference between the students' misconception and the goal conceptions of the unit are illustrated in the Table 1.

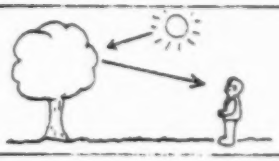
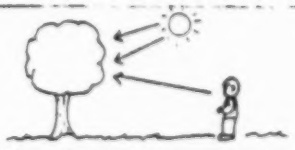
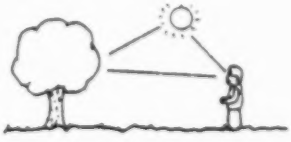
One paragraph in the book begins by talking about the necessity of light for seeing. Instead of asking a question to get students to focus on the conception of how we see illustrated in Figure 1, however, the text drives the discussion and student thinking away from the central issue by asking, "When do you think lights made by people are helpful?" As a result, the discussion

Table 1

Student Responses to a Question About How People See

Question: This boy sees the tree. Draw arrows to show how the light from the sun helps him to see the tree.



Description of Response	Illustration of Typical Answer	Percentage of students (N=125)
Arrows from sun to tree and from tree to boy (correct)		6
Arrows or lines outward from sun only. No arrows between tree and boy (incorrect)		53
Arrows outward from sun and from boy to tree (incorrect)		11
Line between boy and tree, but no indication of direction (ambiguous)		10
Other incorrect responses		6
No response or "I don't know."		14

generated by the question focused on why people need to see rather than on why light is needed for seeing. Although the question in the text generated a lively discussion with many students coming up with tales of what would happen if there were no light, the discussion did nothing to help students gain a new understanding of light and seeing.

There is no question posed at the end of the only paragraph in the first section of the text that explicitly explains how bouncing light helps people see. After a student read this paragraph aloud, Ms. Lane did not stop to explain the concept of reflected light or to point out that this was an important paragraph. Instead, she called on another student to continue reading. Because she did not ask a question about it, she never became aware that her students had no understanding of the principle of reflected light.

Thus, the questions posed by Ms. Lane were taken from the textbook, were generally easy for students to answer using their everyday experiences, and did not serve a diagnostic role in helping Ms. Lane understand her students' thinking. They did not challenge students to think about light in more scientific ways. In fact, the questions posed in the text misled students into thinking that this was all stuff they already knew.

Using such a questioning pattern, Ms. Lane asked lots of low-level, factual questions and open-ended kinds of questions about student opinion. However, she rarely posed questions that required students to link concepts presented in the text with their stories about light in the everyday world. In the section on vision, for example, Ms. Lane quizzed the students repeatedly on naming the parts of the eye. There was little discussion, however, of the functions of the eye parts. When functions were discussed, emphasis was not placed on the role of light in vision. The two topics--light and seeing--were treated as two unrelated topics. Thus Ms. Lane typically missed opportunities

to ask students questions that would force them to apply new concepts to real world phenomena.

Responses to students' answers. When Ms. Lane did ask questions that demanded more than a fact or opinion, students often had difficulty answering the questions. How did Ms. Lane respond to these difficulties? Frequently, she changed the questions and rephrased them to help students come up with the right answer. Notice in the following example how an initial question that asked for a student explanation was changed into a series of factual level questions:

Ms. Lane: What is the function of the optic nerve? (Waits; no response.) What is it that a nerve does? What do they do?

Heidi: Tells whether it is hot or cold.

Ms. Lane: Uh. O.K., they send what?

Students: (calling out) Messages.

Ms. Lane: Where do they send them?

Students: (calling out) To the brain.

Ms. Lane: Without the optic nerve, could you see?

Students: (unison) No.

Ms. Lane: Because it sends messages of the image to the brain. (She writes the following on the board: Optic nerve leads from the back of eye to the brain.)

Once the students gave a correct answer, even when the wording of the question had given away the answer, Ms. Lane proceeded to a new topic as if these correct answers signified that the students had understood. One- or two-word responses by students to a series of questions were accepted as evidence that students understood how to put these answers together to explain the function of the optic nerve.

Ms. Lane's verbal pattern was to call on students until she got a correct answer and to indicate when a student had answered correctly. Incorrect student answers were either passed over or, more rarely, rejected. Often when Ms. Lane heard an answer that was close to what she was looking for, she would indicate approval that the answer was correct and then restate the answer. However, her restatement was often quite different from the student's answer, as shown by the following classroom excerpt:

Ms. Lane: Then there are cells that contain pigments (in the retina). What do you think they do?

Jim: They store.

Ms. Lane: What might they do? What does pigment have to do with?

Bob: The color of the eye.

Ms. Lane: So you think they might help us see color?

Student: Yeah.

(Ms. Lane goes on to next type of cells, light-sensitive cells)

Bob's answer was referring to the color of the iris of the eye; he was talking about something very different than the pigment-containing cells in the retina that Ms. Lane was discussing. But Ms. Lane heard something about color and accepted an inappropriate answer as if it were correct. She did not probe to elicit improvement of this answer or of other incorrect or half-correct student answers.

She also did not require students to use scientific terms correctly. For example, the students had learned from the text that the scientific definition of transparent is something that light can pass through. However, each time the term came up in classroom discussions, Ms. Lane accepted students' everyday, commonsense definition of transparent as something one can see through. By not insisting that they think about what happens to light and by allowing

students to talk about "seeing through" things, she allowed the persistence of students' misconceptions that we see by directly perceiving objects.

Explanations. Ms. Lane generally depended on the textbook to give explanations of scientific concepts. "Let's read about what our book says about what makes the sky blue or other colors." She rarely even rephrased these explanations unless it became necessary in answering one of the questions posed in the text. Only once throughout the whole unit did she give an explanation of how light enables seeing. Apparently, Ms. Lane assumed that textbook explanations read orally in class provide adequate coverage of topics. She did not ask students if they had understood or if they had any questions about the explanations. One day, after reading an explanation from the textbook about how the eye inverts images, the students confronted Ms. Lane with their confusion:

Ms. Lane: Would you read, Scott, that little section near the illustration?

Scott: The lens of each eye bends light so that the images of things you look at form upside down on the retina. But your brain "reads" the messages about these images in a way that lets you see things right side up.

Pat: I don't get it.

Ms. Lane: O.K., so actually if you look at the second picture, when you look at something it is upside down.

Heather: Why?

Ms. Lane: (comes over to Heather's desk and points at the diagram in her book) I think it is because of the way the light bends. See how the light comes in at two angles from the bottom part. It's rather confusing isn't it? To think that we see everything upside down. (She walks to the front of the room and directs the students to close the books and look at an overhead.)

Ms. Lane appeared uncomfortable giving this explanation and clearly was not intent that her students really understand the concept. When the text was

confusing, Ms. Lane, like most elementary school teachers, lacked the science knowledge to help her students out of their confusion.

In sum, Ms. Lane could be characterized as having what we have termed a didactic approach to teaching. She viewed the textbook as a source of facts and information about science to be presented to students. She covered the concepts in the textbook by having discussions that focused on getting the right answers rather than on understanding and applying principles. Ms. Lane sought no information about her students' understanding of light prior to instruction, and she never became aware of her students' misconceptions.

What did Ms. Lane's students learn from this kind of verbal interaction? Ms. Lane ended the unit feeling all had gone well, but posttests and clinical interviews revealed that students' misconceptions had persisted. Although students were almost always "on task," that task was rarely to think about the meaning of the text. They followed along as their fellow students read orally, and they gave brief answers to the teacher's questions. Most of the student talking that was longer than a word or phrase was the relating of a personal experience that was in some way (often only vaguely) related to the topic at hand. Ms. Lane's students were exposed to idea after idea about light, but they were not stimulated to think about the meaning of these ideas. They viewed science as a mass of information to be memorized. Ms. Lane's absorption with the textbook and the suggested answers to questions given in her teacher's edition prevented her from focusing on what her students were really saying and thinking.

Ms. Ramsey

Another teacher using the same text took a different approach to classroom talk. In this part of the study, teachers were supplied with a set of

transparencies and an accompanying teacher's guide to be used with the textbook. These transparencies were designed to break the "read-and-answer-the-questions" cycle of instruction by first presenting a problem that would elicit common student misconceptions about light and seeing. Students could then contrast their answers directly with a scientific answer given on an overlay. The teacher's guide to the transparencies described common student misconceptions and an explanation of the relationship of these misconceptions to scientific conceptions of light and seeing. Armed with this knowledge, Ms. Ramsey created a very different verbal environment.

Use of the text. Ms. Ramsey chose to eliminate round-robin oral reading. Her teaching focused on getting key principles across rather than on covering all the pages in the text. In fact, she used the textbook only occasionally. For example, the only part of the first section of the text that the students read in class was the paragraph explaining how light bounces off objects to people's eyes. This was the paragraph that had no question at the end of it to indicate its importance. While Ms. Lane had skimmed over it, Ms. Ramsey focused on this section with a 10-minute discussion of how light bounces. Thus, information about her students' conceptual difficulties helped Ms. Ramsey to make content decisions. She was able to *use* the text rather than merely follow it.

Ms. Ramsey also used the textbook for helping students develop study skills. She went through one section with them, constructing a group outline. On another occasion she had them preview a section of the book to predict what they would be reading about. In general, Ms. Ramsey did not rely on the textbook to present information. Instead, she relied on the transparency set and

her own worksheets to organize her presentations of the content. As a result, her verbal interactions with students were quite different from those of Ms. Lane.

Questioning pattern. Ms. Ramsey, like Ms. Lane, did very little direct explaining of concepts. Like Ms. Lane, she asked many questions. However, the nature and function of her questions were very different from that of Ms. Lane's.

First, her questions were more focused on the key issues. She tried to avoid questions not central to the main concepts. She did not, for example, pose questions that would encourage students to tell stories about their personal experiences. Unlike Ms. Lane, she had information from the teacher's guide to the transparencies that helped her understand which concepts were central and which were peripheral.

Ms. Ramsey frequently asked questions that forced students to apply concepts. For example, she taught about color and vision, asking students to use the behavior of light to explain how we see. In asking such application questions, she would sometimes tell the students: "Answer, using what you know about light."

Responses to student answers. An important way in which Ms. Ramsey's verbal behavior differed from Ms. Lane's was the way she responded to student answers to her questions. Daily discussions in her class included much student talk as students explained their ideas. Ms. Ramsey was sensitive to these student explanations and frequently readdressed questions to a student to get a clearer idea of what the student was saying. In contrast to what occurred in Ms. Lane's class, student answers were lengthier, and the teacher

was more likely to interact with a student repeatedly before posing a new question. Ms. Ramsey would also come back to a student after other students had spoken to see if she could get the student to restate a position more precisely using what other students had said. This careful probing of student answers enabled Ms. Ramsey to uncover student misconceptions even when the students' initial answers sounded pretty good and could easily have been accepted as close enough approximations of the "correct" answer. The following classroom excerpt is a good illustration of how Ms. Ramsey follows up on students' statements. The discussion focused on the overhead transparency and overlay illustrated in Figure 1.

Ms. Ramsey: (Shows transparency #2. Puts up the left half of the transparency "Light Travels in Straight Lines" and asks the class why the girl cannot see around the wall.)

Annie: The girl can't see around the wall because the wall is opaque.

Ms. Ramsey: What do you mean when you say the wall is opaque?

Annie: You can't see through it. It is solid.

Brian: (calling out) The rays are what can't go through the wall.

Ms. Ramsey: I like that answer better. Why is it better?

Brian: The rays of light bounce off the car and go to the wall but they can't go through the wall.

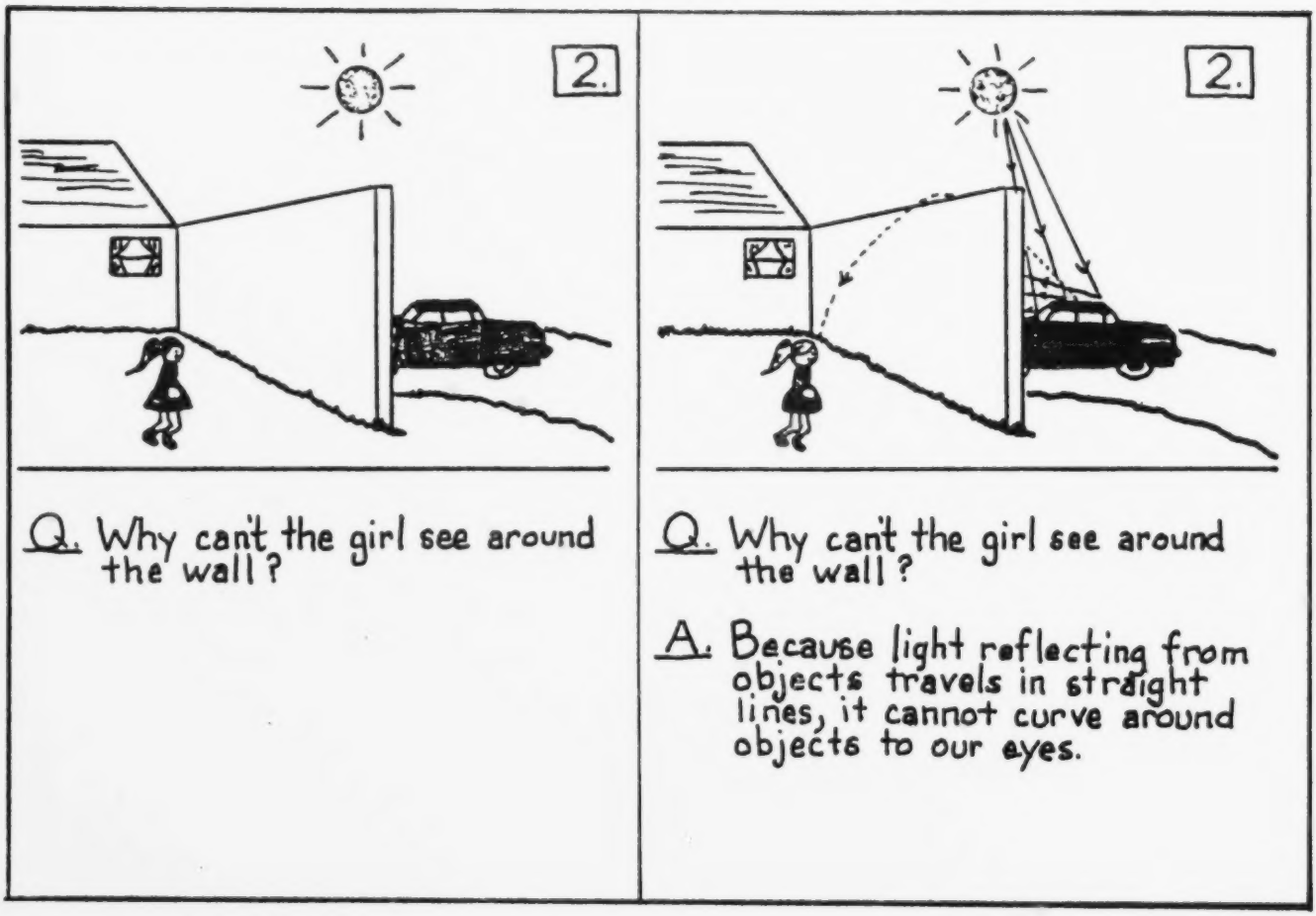
Ms. Ramsey: Where are the light rays coming from originally?

Student: The sun.

Annie: The girl can't see the car because she is not far enough out.

Ms. Ramsey: So you think her position is what is keeping her from seeing it. (She flips down the overlay with the answer). Who was better?

Class: Brian.


2.
Q. Why can't the girl see around the wall?
2.
Q. Why can't the girl see around the wall?
A. Because light reflecting from objects travels in straight lines, it cannot curve around objects to our eyes.

(Transparency) (Transparency with overlay)

2. Light Travels in Straight Lines

Common student answers. Your students will probably know that the line of sight is a straight line. They will know that the girl can't see the car because "the wall is in the way." But *what* is the wall in the way of? Many students may say that the wall is in the way of the girl's "vision" or "eyes."

Textbook answer. The wall is really in the way of the *light* reflected from the car. It prevents the light that reflects off the car from getting to the girl's eyes. Because the light travels in straight lines, it does not curve over or around the wall, so the girl cannot see the car. The girl cannot see the car unless light is reflected off it to her eyes.

Figure 1: Page from Transparencies on Light: Teacher's Manual (Anderson & Smith 1983b) illustrating the transparency and overlay used by Ms. Ramsey (p. 148).

Ms. Ramsey: (to Annie) Would she be able to see if she moved out beyond the wall?

Annie: Yes.

Ms. Ramsey: Why?

Annie: The wall is blocking her view.

Ms. Ramsey: Is it blocking her view? What is it blocking?

Student: Light rays.

Ms. Ramsey: Light rays that are doing what?

Annie: If the girl moves out beyond the wall, then the light rays that bounce off the car are not being blocked.

Once Ms. Ramsey had uncovered misconceptions or inaccuracies in student answers, she asked questions to lead students to realize the inadequacies of their answers. Whereas Ms. Lane asked giveaway questions to lead students to correct answers, Ms. Ramsey asked questions that challenged students to develop more appropriate answers. Annie did not get by giving yes/no answers; she eventually was able to give an explanation that demonstrated understanding of the link between the concept of bouncing light and an everyday phenomenon.

Ms. Ramsey gave careful feedback to her students. She praised students for precise, careful use of language: "I like that word better. Why is it better?" When students stated a misconception, Ms. Ramsey would often directly point out the inaccuracies of the student's statement:

Ms. Ramsey: What will the apple look like in green light?

Jeff: Black.

Ms. Ramsey: Why?

Jeff: The pigments in the apple absorb the green light so they don't reflect anything.

Ms. Ramsey: The pigments absorb the green light so no light is reflected. What will the plant look like in green light?

Amy: The plant will appear green, because the object is already green.

Ms. Ramsey: No. The object isn't already green. The *light* is green and the object reflects . . .

Amy: Green light.

Another key feature of verbal interaction in Ms. Ramsey's class was repetition. She repeated key ideas in different contexts. Different students were given opportunities to answer the same question. She reviewed the transparencies periodically throughout the unit. The students kept written lists of "summary statements" in their notebooks.

Student learning. Did these differences in the teaching style make a difference in student learning? On the posttest, 64% of Ms. Ramsey's students understood how light enables seeing. This is in stark contrast to the 15% in Ms. Lane's class (Anderson & Smith, 1983a). Because her students were challenged to think about and state their ideas clearly and to give evidence for their ideas, Ms. Ramsey not only knew which questions to emphasize but also had a sensitivity to her students' thinking that enabled her to elicit, analyze, and respond to student talk effectively. Ms. Ramsey was not just giving students new ideas to memorize. Instead, she was diagnosing their misconceptions and using this knowledge to guide them in the difficult process of changing their ideas about light and seeing.

Contrasting the teachers' approach to teaching, we would characterize Ms. Lane's approach as didactic and that of Ms. Ramsey as exhibiting *conceptual change*. In this approach, the teacher uses strategies that will help students *change* their experientially based ways of thinking about natural phenomena (misconceptions) to more scientifically appropriate ways of understanding phenomena. Thus, the teacher is concerned with much more than just

presenting scientific concepts to students. Instead, teachers must help students see the relationships/contrasts between their own ideas and the ideas that science has generated if students are going to make sense of the scientific ideas.

Ms. Kain, Year One

During the first year Ms. Kain was observed, she used activity-based curriculum materials--a series of experiments and discussions outlined in the Science Curriculum Improvement Study (SCIIS) Program teacher's guide (Knott, Lawson, Karplus, Their, & Montgomery, 1978) designed to help students understand that plants are producers: They get their food by making it themselves using sunlight, air, and water. Only plants can convert nonfood raw materials into food in a process called photosynthesis.

Use of the curriculum materials. Ms. Kain had no student textbook. She relied on the SCIIS teacher's guide for directions about how to do the experiments and as her source of questions for discussion. She interpreted the guide as presenting what we have labeled a *discovery* orientation to teaching. It was her belief that the experiments and discussions would lead students to figure out the scientific goal conceptions.

Questioning and responding to students. Consistent with a discovery view of learning and an experimental approach to science teaching, Ms. Kain's questions, which came from the SCIIS teacher's guide, focused on getting students to think about the experiments. Ms. Kain asked students to make predictions, describe observations, and explain experimental results. Discussion sessions primarily involved describing observations and exploring students' explanations of the observations. The following section from a classroom transcript exemplifies the typical discourse pattern of the classroom:

Ms. Kain: Where do they [plants in the dark] get their food?

John: Sun isn't everything that makes a plant grow. They've got the dark, the water, and they've got the cells inside them that give themselves food. And the dirt gives them food and stuff. So they don't just need sun to grow. They have other things to help them grow.

Ms. Kain: Uh huh. O.K. Anyone else?

Susan: Maybe it's something in the air that helps them grow. A chemical in the air.

Ms. Kain: They're beginning to die, don't you think?

In this discourse, Ms. Kain provided a structure that encouraged students to think about their observations and to generate their own explanations for these observations, but she gave neither information nor evaluative feedback that indicated appropriate scientific thinking. She listened to students' ideas, sometimes repeated the ideas, and then moved on, asking for other ideas or asking a new question. Students' answers were all received with neutral acceptance by Ms. Kain. They were neither praised nor rejected. In the segment above, both Susan and John are making statements that reflect important misconceptions about how plants get food (e.g., that plants can get food from the soil or from the air), yet Ms. Kain did nothing to make the students doubt that their ideas were acceptable. She did not probe students' explanations or try to help students change their ideas. She just encouraged students to have ideas.

Explanations. Ms. Kain hoped that students would come to their own conclusions about plants' needs for light and food without explicit explanations from her. When the teachers' guide called for the teacher to present the concept of photosynthesis, Ms. Kain gave her students a brief explanation of the concept. This explanation came toward the end of a lesson and was followed by

student discussion not directly relevant to photosynthesis. The teacher then used questioning to review plants' source of food. She accepted students' answer of "the sun" as a source of food, not taking the opportunity to point out the incompleteness of such an answer. The word "photosynthesis" did not come up again until a brief review on the last day of the unit. Thus, Ms. Kain's explanation of photosynthesis was done in a cursory fashion without emphasis.

Instead of emphasizing the development of conceptual understanding, Ms. Kain emphasized the process of doing experiments. She talked a lot about how to carry out experiments and how to record data and hardly at all about photosynthesis. Although such process goals are important, we have our doubts about scientific processes as they were taught in Ms. Kain's class. The experiments seemed to her students to be an elaborate way of showing that plants need light to grow--something that they already believed.

Student learning. Our posttests clearly revealed that Ms. Kain's students had not given up their belief in a number of fundamental misconceptions after this six-week unit. Only 7% understood the scientific conceptions that plants get their food only by making it themselves (Roth, 1984). Students' main source of information had been the experiments, and they interpreted these in terms of their own preconceived notions about plants without recognizing the dissonance between their own ideas and experimental results. They did not use the concept of photosynthesis to explain the experimental results. They continued to view plants' food as the raw materials that plants take in from the environment. By giving up the idea that plants take in their food, students failed to make a fundamental distinction between plants as producers of food and animals as consumers of food.

In always encouraging open-ended responses from students without probing for evidence and clarification, Ms. Kain left students with the impression that all of their ideas were correct and that no one answer was better than the others. The students were not given a useful way of deciding whose ideas were most appropriate.

Ms. Kain, Year Two

During the second year Ms. Kain was involved in the study, she used a researcher-written student textbook (Roth, 1985) in conjunction with the SCIIS experiments. The textbook was written to address more explicitly students' misconceptions about plants' food. The text and accompanying teacher's guide were designed to help students relinquish their misconceptions about food for plants in favor of the scientific concept of photosynthesis. The text posed questions to elicit students' misconceptions, provided evidence and questions to challenge students' misconceptions, presented an explanation of photosynthesis that made sense from the students' perspective, and supplied many application questions. The teacher's guide version of the text gave the teacher information about (a) the purposes of each question, (b) appropriate scientific answers to questions, and (c) likely student responses and ways to spot misconceptions revealed in these responses.

Use of the text. Ms. Kain continued to use the SCIIS teacher's guide for procedural information about running the experiments, but used the new text to structure all discussions sessions. As the unit progressed and the experiments were all either completed or underway, Ms. Kain came to rely almost exclusively on the teacher's guide to the new text for her planning and teaching of lessons. Like Ms. Lane, Ms. Kain generally had her students do round-robin oral reading of the text, stopping only to discuss questions posed in

the text. However, the kinds of questions asked and the ways Ms. Kain responded to student answers were very different from those we had seen in Ms. Lane's classroom as well as those she herself had used the previous year.

Questioning and responding to students. The questions posed in the new text focused on eliciting students' misconceptions and on getting students to realize the shortcomings of their misconceptions. Ms. Kain listened carefully to student answers, focusing on any evidence she heard that a misconception existed or was persisting. She kept discussions more sharply focused on the main issues, was clearly attentive to students' misconceptions, and began to provide evaluative feedback to students. She more frequently challenged students' explanations, not just to clarify what students were saying, but to try to change students' thinking. The following classroom excerpt provides an example of this type of questioning pattern. The class is considering why grass seeds planted in the dark sprouted and began growing even without light. Ms. Kain did not just accept the answers given by Lee, Ed, and Bill. Rather, she tried to help each of them focus on the critical idea that the cotyledon provides food for the germinating plant in the dark.

Question: Why did the plants grow in the dark?

Lee: Light isn't the food so it can grow without the light--it had water and stuff.

Ms. Kain: I'm sorry, Kate, it's Lee's turn; if you would like to speak, I would like you to raise your hand. Lee, I couldn't understand you.

Lee: The light isn't the food so it can grow without the light.

Ms. Kain: Yeah, so we're talking though about how it is that it grew in the dark . . .

Lee: It had water and stuff.

Ms. Kain: It had its food?

Lee: Well, it had the cotyledon and everything.

Ms. Kain: Why was that important? . . . that it had its cotyledon?

Lee: It's its food.

Ms. Kain: Okay! Ed?

Ed: They all need water, the reason those in the light look better is because the sun gives it its color and it also helps make those stay healthy.

Ms. Kain: I want to know *why* the grass grew in the dark, I don't want to know about . . .

Ed: Okay, the cotyledon . . . it helped for awhile.

Ms. Kain: So it needed what?

Ed: Cotyledon and water.

Ms. Kain: Why did it need its cotyledon?

Ed: Because it's the food.

Ms. Kain: It's the food! Okay. Bill, what did you put?

Bill: I put the grass grew in the dark because the cotyledon helped it grow until it could (inaudible) . . .

Ms. Kain: What is the cotyledon?

Bill: It's ah, ah, ah, it's the food.

Ms. Kain: It's the food. Okay. The cotyledon is the food which gives the young plant the energy to grow, right?

In addition to guiding the students' thinking toward scientific conceptions, as the above passage illustrated, Ms. Kain also provided more evaluative feedback for students, letting them know if their comments were acceptable or not. As in the example above, she generally responded to unacceptable answers with probes, intended to improve their answers. Acceptable answers were approved with comments and emphasis of key ideas such as in the following:

Jerry: They no longer have food that they need to continue living and growing.

Ms. Kain: (Enthusiastically) They do not have the food! They do not have the food to continue growing. They don't have the food to provide them with the energy to continue growing. Okay? That's why they died. They don't have the food to give them the energy to continue growing. That's *very* important.

Another difference in the questioning pattern during the second year was Ms. Kain's use of many application questions. An overhead transparency showing plants at different stages of growth was used to review plants' sources of food at each stage. A newspaper article that included drawings of plants was used for a similar review discussion. Finally, Ms. Kain used every application question in the new student text, having students write out answers to the questions before discussing each one in class.

Thus Ms. Kain's questioning and responses to the students during the second year were sharply focused on the critical issues and on students' misconceptions. Students were probed and guided until they could give scientifically appropriate answers, and Ms. Kain let them know whether their ideas were acceptable or not. Imprecise uses of words and half-complete answers were not accepted by Ms. Kain, and students were given many chances to apply newly learned concepts.

Explanations. Ms. Kain also took a very different approach to explaining concepts when she used the new textbook. She decided that she was going to have to take a much stronger role than she had the previous year in directing students' thinking if they were every going to make sense of photosynthesis. As a result, she had students read explanations of key concepts in the student text. In discussing these explanations, Ms. Kain repeated and rephrased

textbook explanations. She also came back to these explanations repeatedly during the unit.

For example, Ms. Kain explained the concept of photosynthesis during four separate lessons. Each time, she tried to explain it a different way--one time talking about photosynthesis as a chemical reaction with molecules being rearranged, at another time describing it as a combination of light, air and water occurring inside the plant. Ms. Kain also hung up a poster summarizing the main points of the process and had her students take notes from it. In answering application questions, she reminded them to use the key concepts listed on the poster. This repetition was an important feature of her explanations during the second year.

Student learning. During the first year, Ms. Kain had asked the students in frustration, "How many of you feel we could have learned just as much in less time?" In the second year, the students showed they could learn more in less time. Although the instructional unit was cut down from 23 lessons in the first year to 16 lessons in the second year, the students in Year 2 developed significantly better ideas about photosynthesis. Seventy-nine percent of the students developed the idea that plants' only source of food is photosynthesis. This in contrast with 7% during Year 1. In addition, students' abilities to answer application questions with appropriate scientific explanations was greatly improved (Roth, 1984).

Summary of the Case Studies

These three case studies are representative of a number of case studies we conducted as part of our research (see Smith & Sendelbach, 1982; Slinger, Anderson, & Smith, 1982; Smith & Anderson, 1984; Eaton, Anderson, & Smith,

1984). It seems clear from these studies that the teachers' verbal strategies play a crucial role in children's comprehension of science, and that those strategies are affected by the materials teachers use. Certain patterns of verbal interactions were more successful in facilitating student comprehension than others.

Ms. Lane let the textbook guide instruction and provide explanations for students. Classroom talk consisted of discussions about questions posed in the book, with the teacher calling on students until the correct answer was given. The students failed to learn from this didactic approach.

Ms. Ramsey taught the same unit using the same textbook with much better success. She relied heavily on the researcher-developed overhead transparency set. With the information provided by these materials, she was able to recognize critical student misconceptions and help students develop more appropriate scientific conceptions.

Ms. Kain's first-year teaching demonstrated that merely emphasizing hands-on experiments will not solve students' learning problems. With her discovery approach to science learning, she created a verbal climate characterized by much student talk about their observations and about their explanations for experimental results. Teacher explanations were noticeably absent. Student comprehension in this classroom was no better than in the textbook-dominated classroom of Ms. Lane.

During the second year, Ms. Kain used a textbook in addition to the hands-on experiments. Like Ms. Lane, she followed the text closely, using round-robin reading and pausing to ask questions. However, the textbook was quite different from Ms. Lane's textbook, and this was influential in helping Ms. Kain talk with her students in a way that was much more conducive to

student learning. Like Ms. Ramsey, she developed a successful conceptual change teaching strategy.

Discussion

The knowledge about teaching and learning accumulated from our study of science teachers suggests that students will not be able to comprehend science instruction or textbooks unless the teacher talks to them in ways that will help them to relinquish or modify their misconceptions in favor of scientific views. To do so, instruction must induce conceptual change in students. The teacher must be actively involved in diagnosing student misconceptions, responding to student misconceptions, presenting content in a way that engages students and makes sense to them, and guiding students to change misconceptions to more scientific views. The teacher must think not only about the scientific content but also about the students' ideas. Our studies have shown, however, such thinking is rare among teachers using currently available commerical science textbooks and curriculum materials.

Conceptual Change Teaching

Our research, including the case studies presented in this paper, leads us to suggest that there are systematic differences between the verbal behavior of successful conceptual-change teachers and that of other teachers. Some of those differences are summarized below.

Eliciting and responding to student misconceptions. Teachers need to be asking questions that will elicit students' misconceptions, continually considering how these misconceptions are influencing students' responses to instruction, and challenging these misconceptions. Ms. Lane was so absorbed with following the textbook and getting students to give right answers that

BEST COPY AVAILABLE

she failed to track her students' thinking. Ms. Kain, during Year 1, elicited her students' misconceptions but she did nothing to make students realize the shortcomings of their ideas. Both Ms. Ramsey and Ms. Kain, Year 2, used information provided in their curriculum materials to take a more effective role in understanding and changing student misconceptions.

Focusing on explanations. Teachers need to focus what they say and what their students are saying on the critical "whys" of science. Ms. Kain's Year 1 students had little opportunity to understand the meaning of their science experiments, because they were only directed to think and talk about experimental procedures, observations, and their own explanations of phenomena. Students were busy *doing*, but they were not busy *thinking*, about the relation between their activities and scientific concepts. In Ms. Lane's class, students became acquainted with concept after concept at a factual level but were never challenged to understand the concepts at a meaningful level. In both of these classes, information was presented without making explicit the importance of each piece of information and how they fit together. Science was presented as a string of seemingly unrelated abstract ideas or observations.

In contrast, Ms. Ramsey and Ms. Kain, Year 2, focused on the "whys" by insisting that students give explanations for their observations and ideas and by frequent repetition of important scientific ideas. Important concepts were linked together to explain natural phenomena. Class discussions were used to refine student explanations, with the teacher emphasizing and repeating key points.

Probing after student responses. Teachers need to know more than just what questions to ask; they also need to know how to respond to student statements. Ms. Kain, Year 1, sometimes asked important "why" questions. However,

she failed to use these questions and the student responses they elicited to encourage student learning. In contrast, when she was given information about likely student responses and their significance, she responded to student statements in ways that got students to think more carefully about the meaning of the science content. This clearly enhanced her instructional effectiveness. Ms. Ramsey also probed when her students' responses were incorrect or incomplete, helping them to modify and clarify their thinking.

Balancing open-ended and closed discussions. There must be a balance between open-ended verbal interactions and directed, structured discussions that lead to closure and consensus. Dependence on only one of these patterns was not successful. Ms. Kain, Year 1, stimulated students to think and talk about their ideas; but without direct guidance from her, students failed to change their ideas. Both Ms. Ramsey and Ms. Kain were able during the second year to elicit students' ideas and then provide direct, structured discussions to lead the students to develop more scientific views. They both realized that, whereas there were times to encourage students to think creatively and divergently, there were also times to explain directly scientific ideas. They were not afraid to distinguish among poor answers, good answers, and best answers, and they clearly communicated to students why certain answers were better than others.

Providing practice and application. Teachers need to ask questions that will allow students to practice applying newly learned scientific conceptions. Such questions not only enable students to see the usefulness of scientific conceptions, they also give the teacher the chance to diagnose persisting misconceptions and to guide students in their thinking. Students in the more

successful classrooms (Ms. Ramsey and Ms. Kain, Year 2) had many more opportunities to apply the concepts they were learning to a variety of real-world situations and to find out whether they were doing so successfully or not.

The Influence of Curriculum Materials

The textbook used by Ms. Lane and Ms. Ramsey was typical of science textbooks. It presented scientists' explanations of light and seeing without any sensitivity to students' misconceptions. It failed to emphasize points that are critical if students are going to change or give up their misconceptions, and it made statements that could be interpreted by students in very different ways from those intended by the author. It is difficult to imagine that the majority of students could ever comprehend this text on their own.

These and other problems have led some educators to suggest that we should abandon the text completely and teach science using experiments, demonstrations, and discussions. We have seen from the case study of Ms. Kain, Year 1, that the answer is not that simple. Another possibility is to try to teach students strategies for making sense of the text. However, what kind of strategy is going to help students recognize the differences between their own thinking and the thinking of the scientists who wrote the textbook? This would require quite sophisticated reading that would be difficult for most fifth graders.

In our research, we attacked the problem by developing new curriculum materials that altered patterns of questions and explanations and teachers' guides that provided the critical information teachers need to help students change their misconceptions and understand science concepts. In Ms. Ramsey's case, the materials were visual aids (transparencies) and had the effect of putting much less emphasis on the student textbook. For Ms. Kain's class, a

new kind of textbook was written. In both of these curriculum development efforts, knowledge of specific student misconceptions and unproductive patterns of student thinking was used to design instruction that would (a) elicit and challenge students' misconceptions, (b) provide reasonable scientific explanations that would contrast with student conceptions yet still make sense to students, and (c) furnish students with the opportunities to apply the newly learned concepts.

Our work with Ms. Ramsey, Ms. Kain, and other teachers has shown that science teaching and science curriculum materials, including textbooks, can be improved by using knowledge of student misconceptions to develop conceptual change instructional strategies. This research suggests that a new model of curriculum development, in which the author writes from a solid understanding of students' commonsense thinking, may enable us to develop textbooks and other materials that will improve teaching strategies and student comprehension.

Conclusion

A major goal of science instruction is for students to develop sound reasoning, thinking, and problem-solving skills and to gain a deeper understanding of their world. Existing science programs are failing to help students meet these goals. However, if teachers can become more sensitive to their students' thinking and to the need for conceptual change, science instruction can be improved. In a conceptual-change model of instruction, the teacher cannot just follow whatever curriculum materials s/he is using. Rather, the teacher must be able to give thoughtful consideration to how students are responding to instruction and act responsively. Decisions on when to allow exploration and open-ended thinking and when to give very direct,

explicit explanation, for example, should be based on what is needed to help students give up or modify their misconceptions in favor of more scientific views.

Textbooks and curriculum materials influence teachers in a variety of important ways. They can encourage ineffective teaching strategies, or they can be important tools in helping teachers give explanations that are appropriate for their students and guide student thinking during teacher-student verbal interactions.

References

Anderson, C. W., & Smith, E. L. (1983a, April). Teacher behavior associated with conceptual learning in science. Paper presented at the Annual meeting of the American Educational Research Association, Montreal.

Anderson, C. W., & Smith, E. L. (1983b). Transparencies on light: Teacher's manual (Research Series No. 130). East Lansing: Michigan State University, Institute for Research on Teaching.

Blecha, M. K., Gega, P. C., & Green, M. (1979). Exploring science: Green book, Teacher's edition (2nd ed.). River Forest, IL: Laidlaw Brothers.

Eaton, J. F., Anderson, C. W., & Smith, E. L. (1984). Student misconceptions interfere with science learning: Case studies of fifth-grade students. Elementary School Journal, 84, 365-379.

Knott, R., Lawson, C., Karplus, R., Their, H., & Montgomery, M. (1978). Communities (Level 5): Teacher's guide (SCIIS). Chicago: Rand McNally.

Rosenshine, B. (1979). Content, time, and direct instruction. In P. L. Peterson & H. J. Walberg (Eds.), Research on teaching (pp. 28-56). Berkeley: McCutchan.

Roth, K. J. (1985). Food for plants: Teacher's guide (Research Series 153). East Lansing: Michigan State University, Institute for Research on Teaching.

Roth, K. J. (1984). Using classroom observations to improve science teaching and curriculum materials. In C. W. Anderson (Ed.), Observing science classrooms: Perspectives from research and practice (1984 Association for the Education of Teachers in Science Yearbook, pp. 77-102). Columbus, OH: ERIC/SMEAC.

Roth, K. J., Smith, E. L., & Anderson C. W. (1983). Students' conceptions of photosynthesis and food for plants. Paper presented at the annual meetings of the American Educational Research Association, Montreal.

Slinger, L., Anderson, C. W., & Smith, E. L. (1982, April). Studying light in the fifth grade: A case study of text-based science teaching. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Fontana, WI.

Smith, E. L., & Anderson, C. W. (1984). Plants as producers: A case study of elementary school science teaching. Journal of Research in Science Teaching, 21: 685-698.

Smith, E. L. & Sendelbach, N. B. (1982). The programme, the plans, and the activities of the classroom: The demands of activity-based science. In J. K. Olson (Ed.), Innovation in the science curriculum: Classroom knowledge and curriculum change (pp. 72-106). London: Croom-Helm.